

Resource Materials

Further Information on Preliminary Risk Analysis

Preliminary Risk Analysis

■ Introduction

- **Performing a preliminary risk analysis**
- **Updating a preliminary risk analysis**

Coast Guard Preliminary Risk Analysis

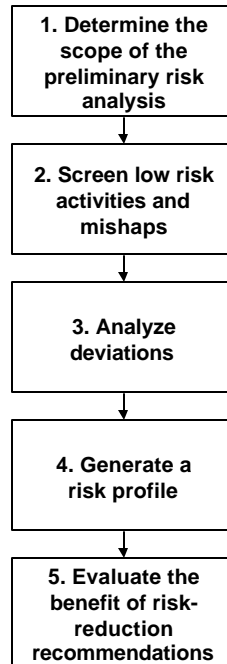
The preliminary risk analysis is a streamlined loss-centered risk assessment approach. The primary objective of the technique is to characterize the risk associated with significant loss scenarios. This is a team-based approach relying on the systematic examination of the issues by subject matter experts and stakeholders. The team postulates combinations of mishaps, most significant contributors to losses, and safeguards. The analysis also characterizes the risk of the mishaps and identifies recommendations for reducing risk.

Preliminary Risk Analysis

- **Introduction**
- **Performing a preliminary risk analysis**
- **Updating a preliminary risk analysis**

Performing a Preliminary Risk Analysis

This section describes the detailed steps involved in performing a preliminary risk analysis.



Overview of the Steps for Performing a Preliminary Risk Analysis

1. Determine the scope of the preliminary risk analysis

Determining the scope includes identifying the hazards, mishaps, and activities that will be analyzed.

2. Screen low risk activities and mishaps

Screening items streamlines the analysis by eliminating in-depth review of low risk items.

3. Analyze mishaps

Evaluate the mishaps of each activity within the scope of the analysis.

Evaluating mishaps is the fundamental activity in the preliminary risk analysis. This involves identifying mishaps, most significant contributors, and safeguards.

Characterize mishap risk

Characterizing the risk associated with mishaps involves assigning risk scores, risk index numbers (RINs), and certainty of the risk estimate to each mishap.

Develop recommendations

Often, mishap risk is high or uncertain, and recommendations to lower the risk or recommendations for further analysis are necessary.

4. Generate a risk profile

Determine the risk contribution of mishaps

This step identifies the mishaps that are the high risk contributors.

Determine the risk contribution of activities

This step determines which activities are the high risk contributors.

Generate a risk matrix

This step builds the risk matrix. A risk matrix illustrates the distribution of mishaps in various frequency categories.

Determine the range of mishap frequencies

This step determines the estimated frequency of each class of mishap.

Compare frequency estimates/historical experience

Performing this step compares the estimated frequencies of mishaps with historical experience.

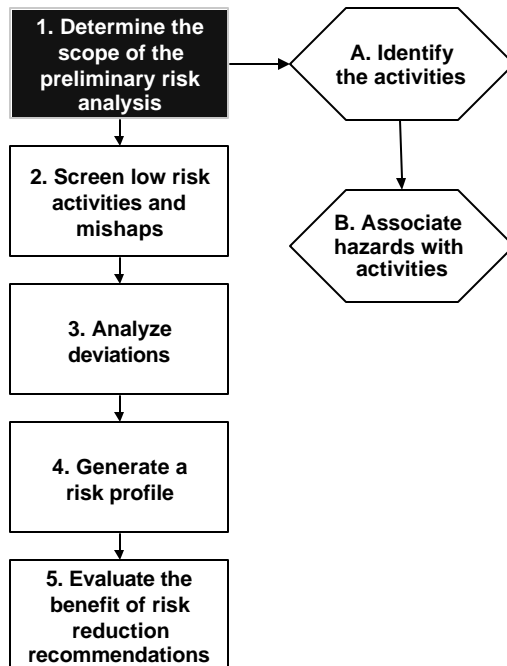
5. Evaluate the benefit of risk reduction recommendations

Determine revised frequency scores and RINs

This step determines revised frequency scores and RINs for mishaps affected by the recommendation.

Determine the benefit of implementing recommendations

Performing this step involves calculating the range of estimated benefit (risk reduction) from implementing a recommendation.



Step 1. Determine the Scope of the Preliminary Risk Analysis

Determining the scope involves identifying the activities of interest that will be reviewed in the analysis and identifying hazards that may be present when each activity is being performed.

Step 1.A Identify the activities of interest

Activity — a collection of tasks or a single task performed in support of an objective.

Example activities:

- **Cargo transportation: deep draft vessels**
- **Cargo loading/unloading: bulk liquid**
- **Boarding**
- **Damage control**
- **Inspections**

Note:

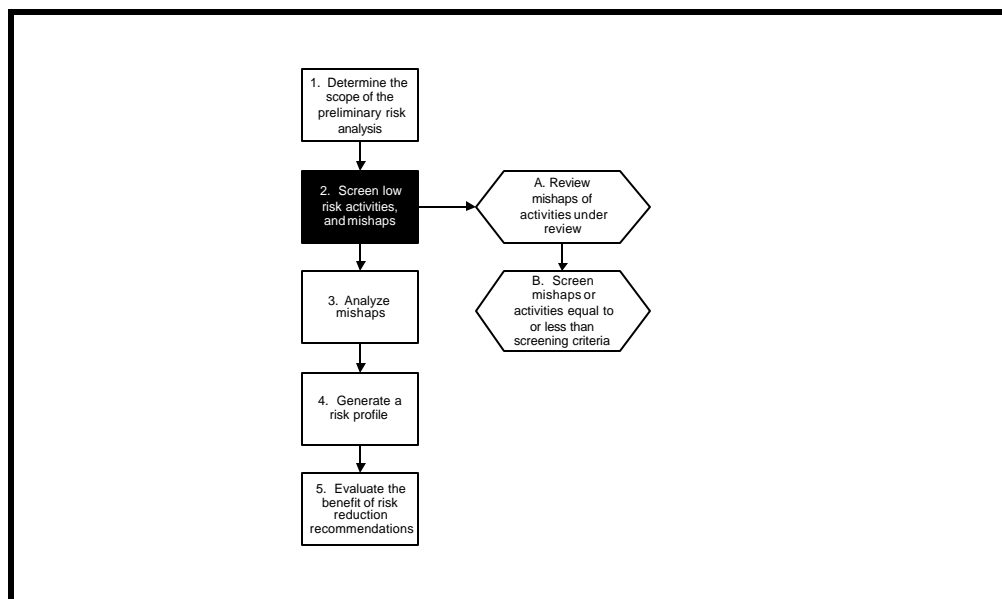
Activities in this section are in bold type.

Step 1.B Associate hazards with activities

There are hazards associated with each activity. Associating hazards with activities identifies the specific hazards and mishaps the analysis team should be considering as an activity is analyzed.

Example: Cargo loading/unloading: container

Activity	Hazard
Cargo loading/ unloading: container	Elevated objects
	Tension/compression
	Elevated personnel
	High pressure
	Onboard equipment motion



Step 2 Screen low risk activities and mishaps

Screening — *determining at a high level that an item is of low risk and will not need to be analyzed in detail*

Screening mishaps or activities allows the analysis team to streamline the preliminary risk analysis process by identifying low risk items and screening them from the analysis. Screening is a systematic activity that can be performed at any stage of the analysis process.

The steps below outline the screening process. These steps should be used during the various stages of the analysis.

Step 2.A Qualitatively review the mishaps that are a part of the activity under review

This is a high level review of the mishaps that is performed to familiarize the analyst just enough to make a high level estimate of overall mishap frequency in the next step. This review may not involve much more than identifying the mishaps. Detailed analysis will follow later in the analysis sessions.

Step 2.B Screen the mishaps or activities if it is estimated to have frequency scores equal to or less than screening criteria with at least a Medium certainty

After reviewing the mishaps, determine whether their collective frequency scores are less than or equal to the screening criteria. Remember that this is a high level qualitative estimate. Detailed analysis will follow if the item is not screened.

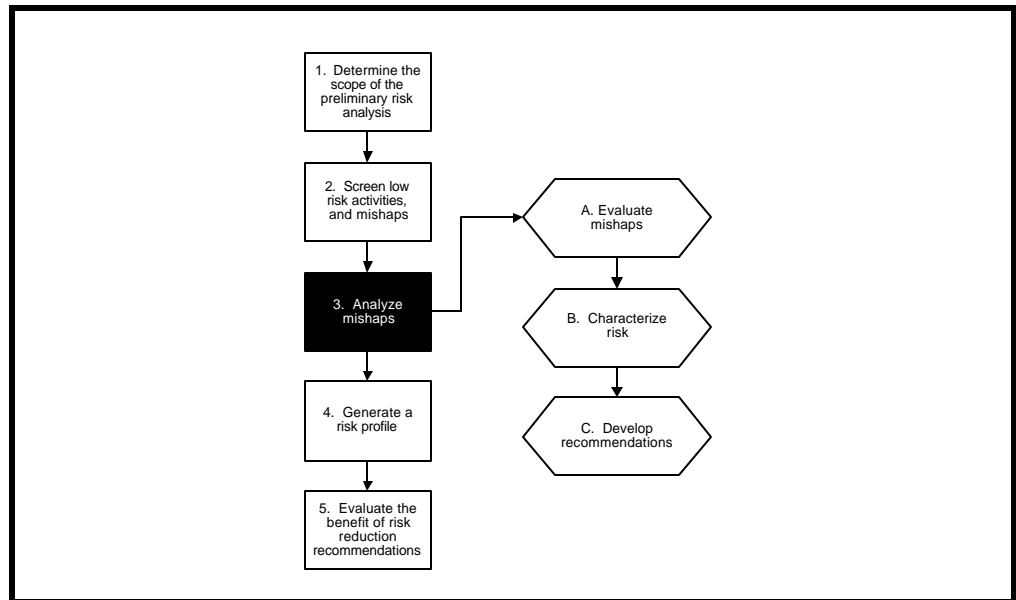
Note:

If any of the mishap frequencies are estimated to be higher than the screening criteria, the mishap should not be screened. If all mishaps within an activity have estimated frequencies less than the screening criteria, the activity can be screened.

The screening criteria are defined by management systems and are the level of risk (frequency of occurrence of a Category 1,2,or 3 mishap) that management is not willing to pursue for further analysis.

IMPORTANT!

The screening process should be applied to all activities at the beginning of the analysis. The set of nonscreened activities will be assessed once all activities have been reviewed in the screening process.



Step 3 Analyze Mishaps

Preliminary risk analysis provides a systematic way to analyze mishaps that may occur while performing an activity. For each mishap, the analysis identifies the most significant contributors to the mishaps and the safeguards in place to prevent the contributors or mitigate the mishaps. The analysis also defines the risk associated with the mishaps as well as recommendations to reduce the risk.

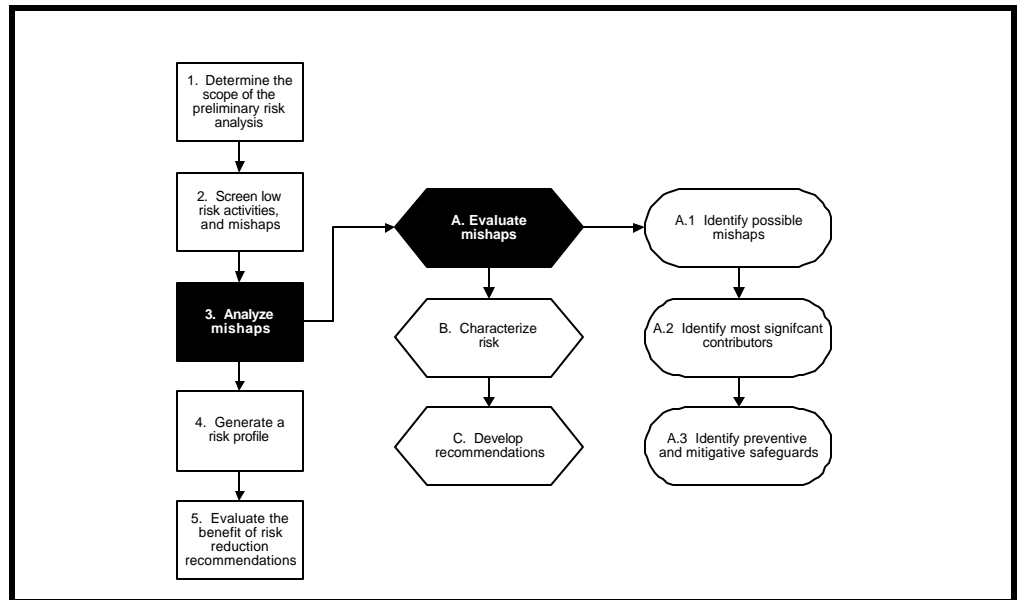
This section presents the method for documenting the analysis and explains the detailed steps for identifying and characterizing potential mishaps, characterizing mishap risk, and developing recommendations.

The analysis documentation table

Typically, analysis software will be used to collect the analysis data. However, the preliminary risk analysis can be documented using a table such as the one on the following page. The table arranges the information in a logical format and allows flexibility in reporting when captured electronically. Within the scope of the analysis, the table includes the activity analyzed, and the mishaps associated with the activity. Each mishap is evaluated during the analysis, completing the analysis table.

Preliminary Risk Analysis									
Activity: Cargo loading/unloading: container									
No.	Mishap	Most Significant Contributors	Frequency			RIN	Certainty	Safeguards	Recommendations
			1	2	3				
1.1	Acute hazard exposure: workers	Dropped objects from cranes Physical injuries during handling operations Slips, trips, or falls during handling operations	3	4	3	1.815	Medium	Personnel qualifications: dock workers Promulgation and enforcement of industry standards: personal protective equipment and safe work practices	Consider establishing crew fatigue guidelines
1.2	Collision with a fixed object	Load shifting Improper movement of a container during loading/unloading Mechanical failure of crane transmission Failure of cable	2	3	4	0.183	High	Personnel qualifications: crane operators Port safety and security: HARPATs (providing general oversight and deterrence) Third party surveys: crane inspections	

Along with the analysis table (or software tool), it is good practice to have a means to record notes or comments pertaining to the information in the table.



Step 3.A Evaluate Mishaps

Preliminary Risk Analysis									
Activity: Cargo loading/unloading: container									
No.	Mishap	Most Significant Contributors	Frequency			RIN	Certainty	Safeguards	Recommendations
			1	2	3				
1.1	Acute hazard exposure: workers	Dropped objects from cranes Physical injuries during handling operations Slips, trips, or falls during handling operations	3	4	3	1.815	Medium	Personnel qualifications: dock workers Promulgation and enforcement of industry standards: personal protective equipment and safe work practices	Consider establishing crew fatigue guidelines

A preliminary risk analysis is performed by systematically evaluating mishaps listed in the analysis tables.

IMPORTANT!

Before analyzing mishaps, consider at a high level all of the potential mishaps associated with the activity being analyzed. Determine whether the activity can be screened.

Steps used to evaluate a mishap

- 3.A.1 Identify possible mishaps of the activity
- 3.A.2 Identify most significant contributors
- 3.A.3 Identify preventive and mitigative safeguards

Step 3.A.1 Identify possible mishaps of the activity

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Activity: Cargo loading/unloading: container									
No.	Mishap	Most Significant Contributors	Frequency			RIN	Certainty	Safeguards	Recommendations
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Mishap — *a loss or accident*

Answer this question when identifying mishaps:

“While performing this activity, what are the potential mishaps that may occur?”

A mishap is any event that can produce a loss of interest. There are three mishap categories which are defined as follows:

Mishap Severity Category	Safety Impact	Environmental Impact	Economic Impact	Mission Impact
Category 1	One or more deaths or permanent disability	Releases that result in long-term disruption of the ecosystem or long-term exposure to chronic health risks	≥ \$2.7M	≥ \$2.7M
Category 2	Injury that requires hospitalization or lost work days	Releases that result in short-term disruption of the ecosystem	≥\$10K and <\$2.7M	≥ \$10K and <\$2.7M
Category 3	Injury that requires first aid	Pollution with minimal acute environmental or public health impact	≥ \$100 and <\$10K	≥ \$100 and <\$10K

A suggested set of mishaps of interest include:

Mishaps of Interest
Capsizing Collision with another vessel Collision with a fixed object Collision with a floating object Grounding Sinking Fire/explosion Drowning Person overboard Environmental impact Acute hazard exposure: workers Acute hazard exposure: public Nonconformance leading to loss of commerce

Step 3.A.2 Identify the most significant contributors to mishaps

Preliminary Risk Analysis									
Activity: Cargo loading/unloading: container									
No.	Mishap	Most Significant Contributors	Frequency			RIN	Certainty	Safeguards	Recommendations
			1	2	3				
1.1	Acute hazard exposure: workers	<p>Dropped objects from cranes</p> <p>Physical injuries during handling operations</p> <p>Slips, trips, or falls during handling operations</p>	3	4	3	1.815	Medium	<p>Personnel qualifications: dock workers</p> <p>Promulgation and enforcement of industry standards: personal protective equipment and safe work practices</p>	Consider establishing crew fatigue guidelines

Most significant contributor — a scenario or initiating event (cause), that if not prevented or mitigated, may result in a mishap.

Answer this question when identifying contributors:

“While performing this activity, what are the most significant contributors of this mishap?”

Contributors to mishaps can be:

- Human error
- Equipment failure
- Hardware system failure
- Administrative system failure

Focus on single events. Include multiple event contributors only in cases where the frequency of the multiple events occurring is High.

Note:

When answering this question, only consider the activity currently under review.

Step 3.A.3 Identify preventive and mitigative safeguards

Preliminary Risk Analysis									
Activity: Cargo loading/unloading: container									
No.	Mishap	Most Significant Contributors	Frequency			RIN	Certainty	Safeguards	Recommendations
			1	2	3				
1.1	Acute hazard exposure: workers	Dropped objects from cranes Physical injuries during handling operations Slips, trips, or falls during handling operations	3	4	3	1.815	Medium	Personnel qualifications: dock workers Promulgation and enforcement of industry standards: personal protective equipment and safe work practices	Consider establishing crew fatigue guidelines

Safeguard — *engineered systems (hardware) or administrative controls for (1) reducing the frequency of occurrence of significant contributors or (2) reducing the likelihood or the severity of mishaps*

Answer this question when identifying safeguards:

“While performing this activity, what are the engineered systems or administrative controls in place to reduce the frequency of the contributors or reduce the severity of the mishap?”

Answer this question with respect to the activity being considered.

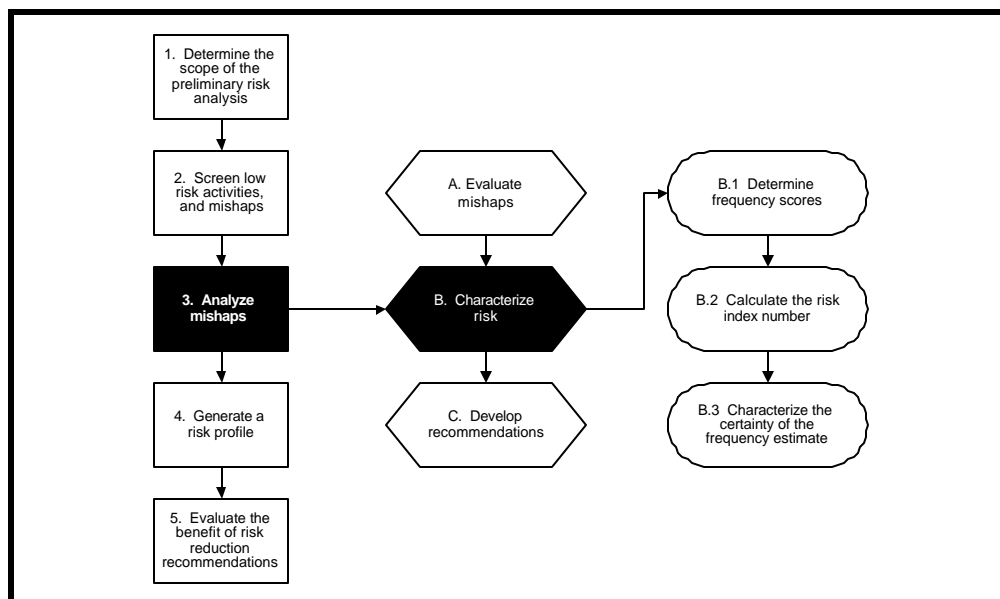
Types of safeguards to consider:

- Hardware (e.g., barriers, alarms, interlocks, redundant pumps)
- Specific procedures and training (e.g., ammunition loading procedure, PQS for deck crew)
- Specific administrative policies (e.g., respirator program)

Avoid becoming too optimistic about safeguard reliability/effectiveness. If the dependability of a safeguard is in question, the conservative approach is to not take credit for it (especially human detection/response and adherence to administrative policies).

Think about each mishap as a scenario.

- Each significant contributor is an initiating event.
- Safeguards are the engineered features or actions that make the most significant contributor or mishap less likely to occur and/or reduce the severity of the mishap.



Step 3.B Characterize the risk of mishaps

Risk — *the combination of the expected frequency (events/year) and consequence (effects/event) of a single accident or group of accidents*

For each mishap, the risk associated with the outcomes must be characterized. This characterization includes frequency and consequence estimates, a risk index number derived from the frequency estimates, and determination of the certainty of the estimate.

Steps used to characterize risk

- 3.B.1 Determine frequency scores
- 3.B.2 Calculate the risk index number
- 3.B.3 Characterize the certainty of the frequency estimate

Step 3.B.1 Determine the frequency of the mishap resulting in Class 1, 2, or 3 severity.

Preliminary Risk Analysis									
Activity: Cargo loading/unloading: container									
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			1	2	3				
1.1	Acute hazard exposure: workers	Dropped objects from cranes Physical injuries during handling operations Slips, trips, or falls during handling operations	3	4	3	1.815	Medium	Personnel qualifications: dock workers Promulgation and enforcement of industry standards: personal protective equipment and safe work practices	Consider establishing crew fatigue guidelines

Frequency — a score indicating the expected number of occurrences per year of the relevant mishap category

Class 1 Mishap — a mishap that is classified as Class 1. For the purposes of risk calculations, Class 1 mishaps are equivalent to a loss of \$2,700,000 or greater (average loss of \$3,000,000)

Class 2 Mishap — a mishap that is classified as Class 2. For the purposes of risk calculations, Class 2 mishaps are equivalent to a loss of less than \$2,700,000, but greater than or equal to \$10,000 (average loss of \$30,000)

Class 3 Mishap — a mishap that is classified as Class 3. For the purposes of risk calculations, Class 3 mishaps are equivalent to a loss of less than \$10,000 but greater than or equal to \$100 (average loss of \$300)

Using the frequency scoring categories in the figure on the next page, assess the frequency of each mishap occurring and resulting in a Class 1, 2, and 3 severity. Only assess the mishap with respect to the activity being considered. Rather than estimating the frequency of each credible mishap's contributors occurring and each associated safeguard failing, make higher level, subjective assessments of the overall frequency of each mishap occurring, resulting in a specific consequence level. Each frequency estimate should be based on cumulative frequencies of contributing events.

Tip:

Use available data from the following sources to develop reasonable frequency estimates:

- Mishap database
- Maintenance database
- Subject matter expert judgment
- Generic/vendor data

Frequency Scoring Categories

Frequency Score Descriptions	Frequency Scores (with indicated frequency bounds)	Example Benchmarks for Assigning Frequency Categories
Continuous Will occur almost continuously (100 or more times per year)	8	
Very Frequent Will occur very frequently (10 to 100 times per year)	7	← One event each week ← One event each month
Frequent Will occur frequently (1 to 10 times per year)	6	← One event each quarter ← One event per year
Occasional Will occur periodically (one time every 1 to 10 years)	5	← One event over 3 years ← One event over 9 years
Probable Will occur a few times over a 50-year period (one time every 10 years to 50% chance over a 50-year period)	4	← 10% chance of an event over 3 years ← 10% chance of an event over 9 years
Improbable Unlikely, but reasonably expected to occur (50% to 5% chance over a 50-year period)	3	← 1% chance of an event over 3 years ← 1% chance of an event over 9 years
Rare Very unlikely, but credible (5% to 0.5% chance over a 50-year period)	2	← 1-in-1000 chance of an event over 3 years ← 1-in-1000 chance of an event over 9 years
Remote Extremely unlikely, but not physically impossible (0.5% to 0.005% chance over a 50-year period)	1	← ~1-in-10,000 chance of an event over 9 years
Incredible Physically impossible or virtually impossible (less than 0.005% chance over a 50-year period)	0	← ~1-in-100,000 chance of an event over 9 years

Step 3.B.2 Calculate the risk index number (RIN)

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Activity: Cargo loading/unloading: container									
No.	Mishap	Most Significant Contributors	Frequency			RIN	Certainty	Safeguards	Recommendations
			1	2	3				
1.1	Acute hazard exposure: workers	Dropped objects from cranes Physical injuries during handling operations Slips, trips, or falls during handling operations	3	4	3	1.815	Medium	Personnel qualifications: dock workers Promulgation and enforcement of industry standards: personal protective equipment and safe work practices	Consider establishing crew fatigue guidelines

Risk Index Number — *a relative measure of the overall risk associated with a mishap*

Calculate the RIN (or average RIN) for each mishap by using the following equation:

$$\text{RIN} = (16.5 \cdot 10^{(Fs1)} + 0.165 \cdot 10^{(Fs2)} + 0.00165 \cdot 10^{(Fs3)}) / 10,000$$

Where:

Fs1 = the frequency score for severity Class 1 mishaps

Fs2 = the frequency score for severity Class 2 mishaps

Fs3 = the frequency score for severity Class 3 mishaps

This equation is derived assuming an average Class 1 mishap is equivalent to \$3,000,000, an average Class 2 mishap is equivalent to \$30,000, and an average Class 3 mishap is equivalent to \$300.

Note:

The RIN is proportional to the dollar/year loss due to the mishap. The loss is based on the average cost of a mishap.

While analyzing mishaps, the average RIN is the only calculation necessary to quantify and compare risks. However, the lower and upper bounds of the risk index number can also be calculated using the lower and upper severity category bounds of each severity category and the lower and upper bounds of the frequency categories. This information is useful for reviewing the entire range of risk associated with a mishap.

The lower bound of the risk index number (RIN_L) can be calculated using the following equation:

$$RIN_L = (2.7 \cdot 10^{(Fs1)} + 0.01 \cdot 10^{(Fs2)} + 0.0001 \cdot 10^{(Fs3)}) / 10,000$$

This equation is derived assuming the Class 1 mishap is equivalent to \$2,700,000, the Class 2 mishap is equivalent to \$10,000, and the Class 3 mishap is equivalent to \$100.

The upper bound of the risk index number (RIN_U) can be calculated using the following equation:

$$RIN_U = (300 \cdot 10^{(Fs1)} + 27 \cdot 10^{(Fs2)} + 0.1 \cdot 10^{(Fs3)}) / 10,000$$

This equation is derived assuming the Class 1 mishap is equivalent to \$3,000,000, the Class 2 mishap is equivalent to \$2,700,000, and the Class 3 mishap is equivalent to \$10,000.

The following three pages contain the complete derivation of all three equations.

Step 3.B.3 Characterize the certainty of the frequency estimate

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Certainty — *the confidence in the frequency assessments of Class 1, 2, and 3 severity categories.*

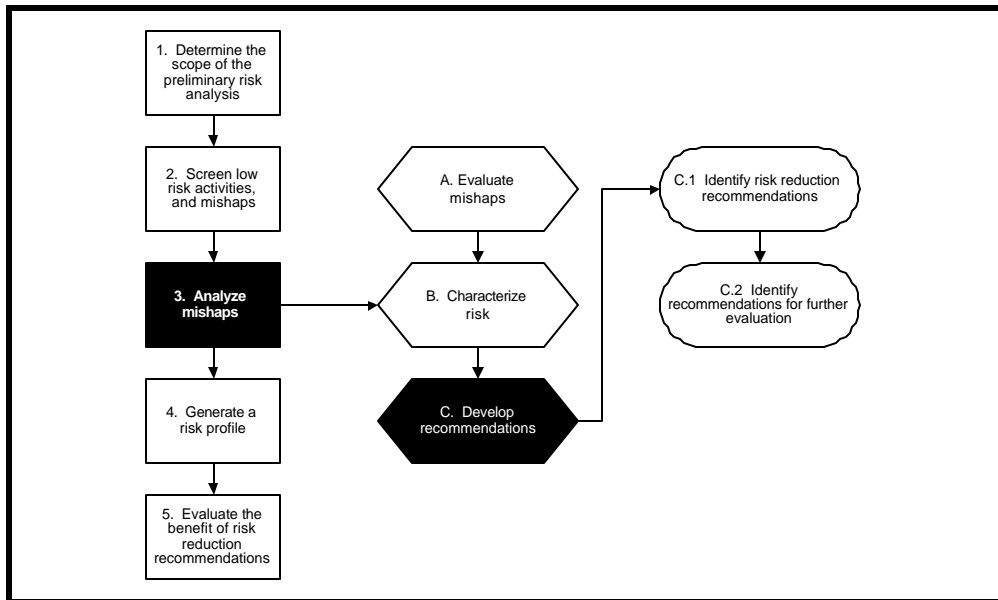
Characterize the confidence in the assessment of the frequency scores for each mishap. This subjective rating helps to qualify the risk estimates. For example, a medium risk mishap with a High certainty may deserve the same or more attention than a high risk mishap with a Low certainty.

Certainty categories:

High — very confident in assigned frequency categories; typically used when (1) there is a strong understanding of mishap mechanisms and/or (2) there have been a significant number of previous occurrences, or there is a large relevant population with few or no occurrences

Medium — comfortable with assigned frequency categories; typically used when (1) there is a moderate understanding of mishap mechanisms and/or (2) there have been only a few (or no) previous occurrences, or there is at least a moderate relevant population with few (or no) previous occurrences

Low — little confidence in assigned frequency categories; typically used when (1) there is no strong understanding of mishap mechanisms and/or (2) there have been few (or no) previous occurrences and relevant populations are small



Step 3.C Develop recommendations

Preliminary Risk Analysis									
Activity: Cargo loading/unloading: container									
No.	Mishap	Most Significant Contributors	Frequency			RIN	Certainty	Safeguards	Recommendations
			1	2	3				
1.1	Acute hazard exposure: workers	Dropped objects from cranes Physical injuries during handling operations Slips, trips, or falls during handling operations	3	4	3	1.815	Medium	Personnel qualifications: dock workers Promulgation and enforcement of industry standards: personal protective equipment and safe work practices	Consider establishing crew fatigue guidelines

Recommendations — suggestions for (1) reducing the risk associated with a mishap and/or (2) providing more extensive evaluation of specific issues

Risk reduction recommendations and recommendations suggesting more in-depth review are necessary for high risk mishaps or mishaps with low levels of certainty.

Steps used to develop recommendations

3.C.1 Identify risk reduction recommendations

3.C.2 Identify recommendations for further evaluation

Step 3.C.1 Identify risk reduction recommendations

Risk reduction recommendations should accomplish one or more of the following:

- Eliminate/mitigate hazards
- Prevent causes (most significant contributors)
- Ensure that existing safeguards are dependable
- Provide additional safeguards
- Mitigate the effects of mishaps

Note:

Be certain that risk reduction recommendations:

- Do not unknowingly increase other risks
 - Are practical
 - Effectively focus on pertinent risk issues
-

Example:

- Consider providing fixed-fire protection for the pumping station
- Consider providing machine guards for the cable/spool pinch-points on the pier winches

Step 3.C.2 Identify recommendations for further evaluation

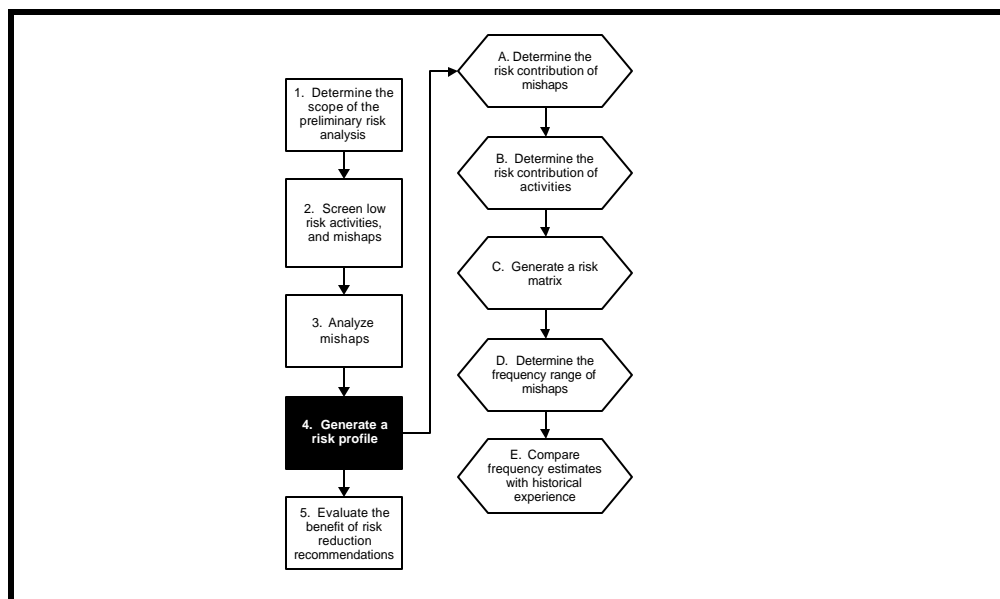
Some mishaps or issues may require a more detailed analysis. Such situations include:

- High risk mishaps/issues where more resolution is needed to develop risk reduction measures
- Potentially significant mishaps/issues with a low level of certainty in the risk assessment or the information gathered about the mishap scenario

Examples:

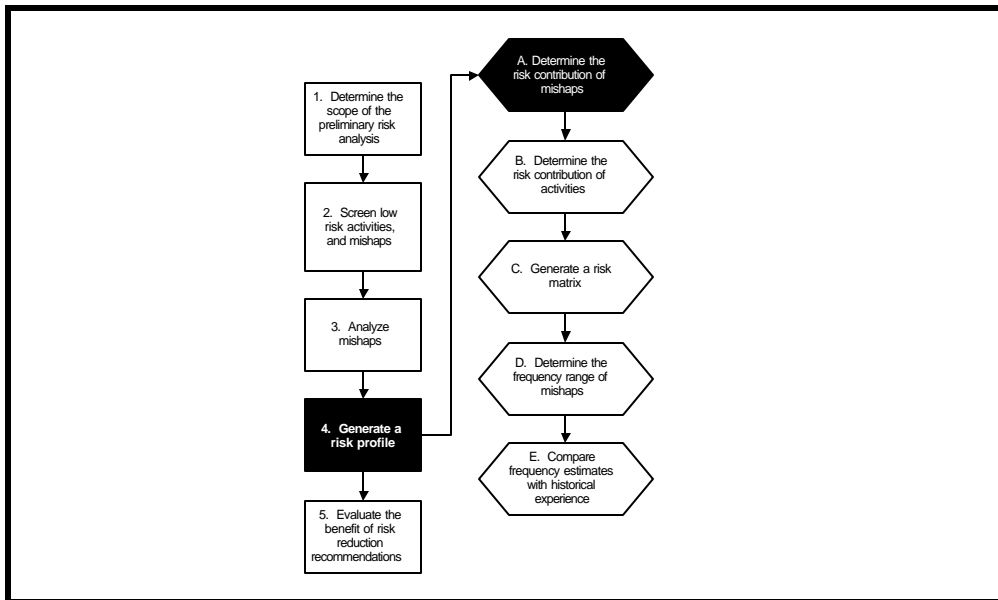
Situation 1 — Consider performing more detailed hazard evaluation of the equipment/procedures used for lifting containers to ensure that existing procedures and equipment configurations/preventive maintenance (1) provide adequate protection against dropping loads and (2) are consistent with good engineering practices

Situation 2 — Consider performing a more detailed analysis of the electrical systems on Pier 14 to specifically identify and evaluate (1) the potential for electrical fires and (2) the potential for electrical shocks of dock workers



Step 4 Generate a Risk Profile

To effectively manage risk, decision makers must analyze the risk associated with a unit class or facility from several perspectives. The preliminary risk analysis provides risk information for each mishap associated with an activity. Risk associated with each mishap is the basic information required to analyze overall risk.



Step 4.A Determine the risk contribution of mishaps

Determining the risk contribution importance (risk contribution) of mishaps provides a means to focus resources as narrowly as possible on mishaps that are estimated to be the dominant risk contributors.

Mishaps Ranked by Risk Contribution	
Activity/ Mishap	Risk Contribution
Cargo transportation: Deep draft vessels Acute hazard exposure: worker	.15
Cargo loading/unloading: Container Acute hazard exposure: worker	.15
Cargo transportation: Deep draft vessels Non-conformance leading to loss of commerce	.14
Passenger trade: Excursion Person overboard	.07

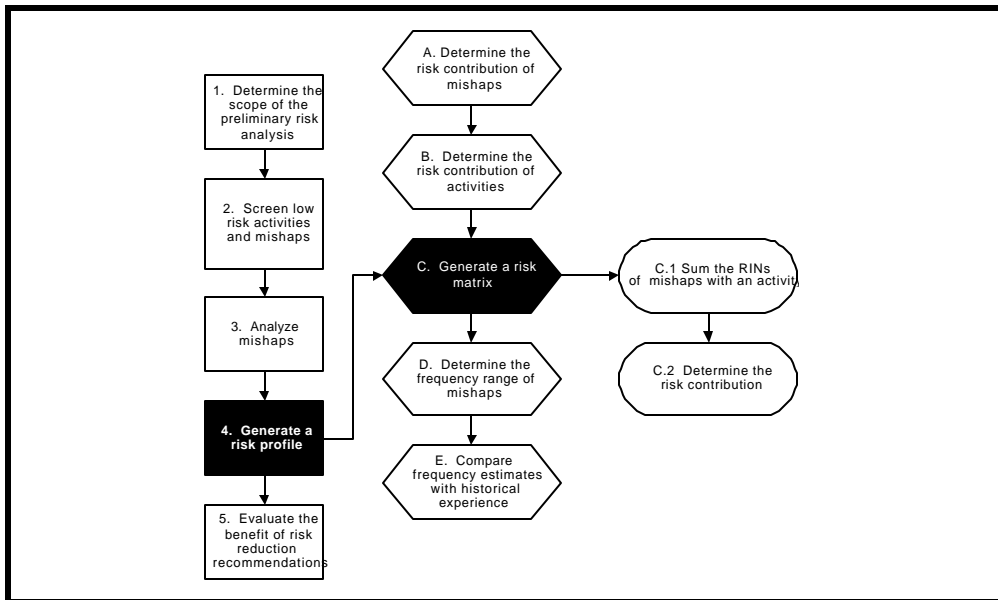
Use the following equation to determine risk contribution of a mishap:
 Risk contribution = RIN (of the mishap)/Total risk (RIN)

Example:

$$\text{Total risk (RIN)} = 2265$$

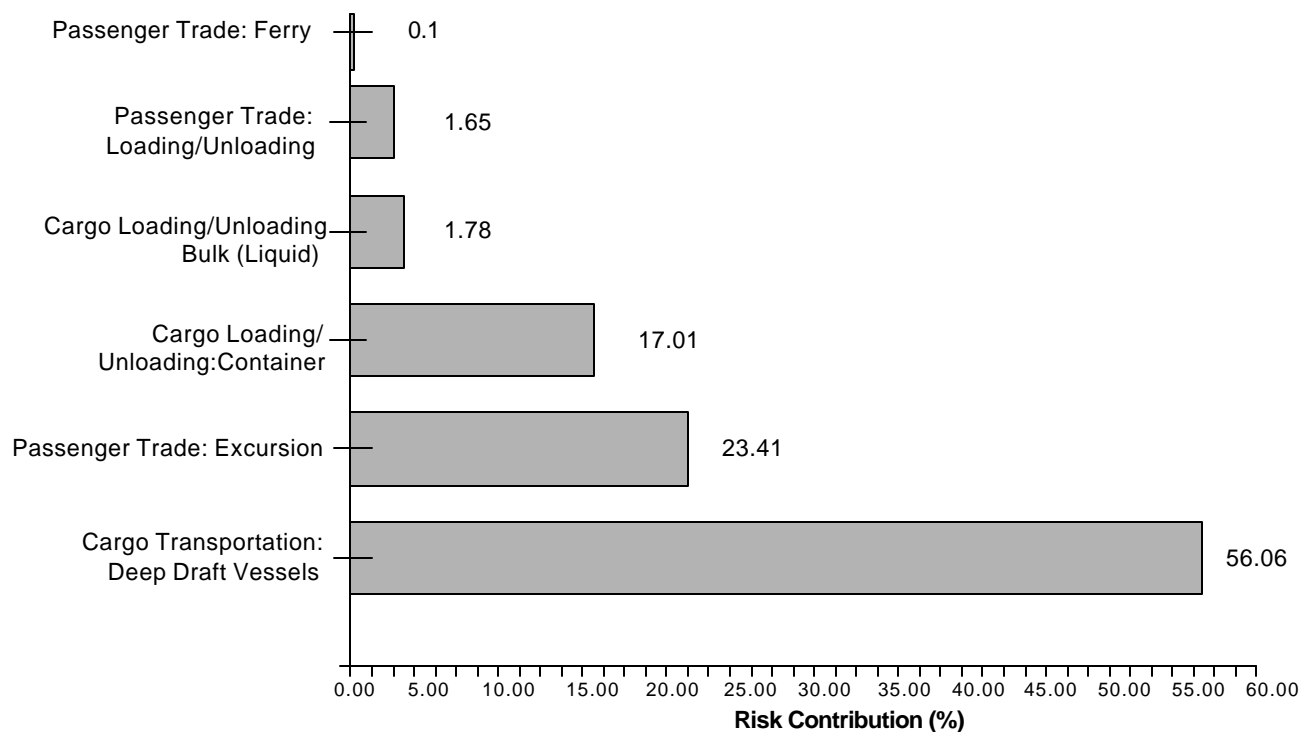
$$\text{RIN for "Passenger trade: Excursion, person overboard"} = 346.5$$

$$\begin{aligned} \text{Risk contribution of "Passenger trade: Excursion, person overboard"} &= 346.5/2265 \\ &= 0.0153 \end{aligned}$$



Step 4.B Determine the risk contribution of activities

Although most risk management resources are targeted as narrowly as possible toward the highest individual risk contributors, some risk management decisions (especially training and research decisions) are frequently based on broader characterizations of risks such as risk associated with an activity (e.g., **Cargo transportation: Deep draft vessels, Passenger Trade: Excursion**). The risk can be graphically illustrated using a histogram. A histogram provides a graphical ranking of the activities displaying each activity's contribution to overall risk.

Risk contribution histogram for activities**Steps used to determine the risk contribution of activities**

- 4.B.1 Sum the RINs of mishaps associated with an activity
- 4.B.2 Determine the risk contribution

Step 4.B.1 Sum the RINs of mishaps associated with an activity

Activity	Mishaps	RIN
Cargo transportation: Deep draft vessels	Acute hazard exposure: worker	346.5
	Non-conformance leading to loss of commerce	330
	Fire/explosion	593
	ΣRIN for Cargo transportation: Deep draft vessels	1269.5
Passenger trade: Excursion	Person overboard	166.8
	Non-conformance leading to loss of commerce	165
	ΣRIN for Passenger trade: Excursion	331.8

As shown above, include all mishaps associated with the activity under review.

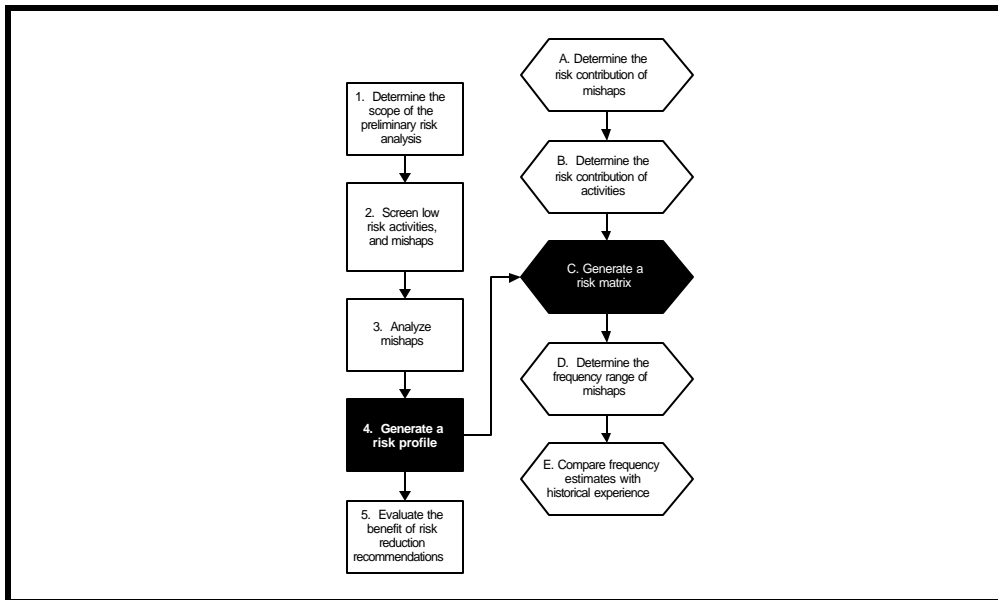
Step 4.B.2 Determine the risk contribution

Divide the total risk for the activity calculated in the first step by the total risk (ΣRIN)

Example:

$$\begin{array}{rcl} \text{Total risk } (\Sigma RIN) & = & 2265 \\ \text{RIN for } \mathbf{Cargo\ transportation: Deep\ draft\ vessels} & = & 1269.5 \end{array}$$

$$\begin{array}{rcl} \text{Risk contribution of } \mathbf{Cargo\ transportation: Deep\ draft\ vessels} & = & 1269.5/2265 \\ & = & 0.56 \end{array}$$



Step 4.C Generate a risk matrix

Risk matrix — *a matrix depicting the risk profile of issues analyzed. Each cell in the matrix indicates the number of mishaps having that frequency and consequence*

	Category 1	Category 2	Category 3
Continuous (8)	0	0	0
Very frequent (7)	0	2	2
Frequent (6)	0	5	5
Occasional (5)	1	9	9
Probable (4)	2	15	22
Improbable (3)	6	14	14
Rare (2)	11	17	10
Remote (1)	36	20	3
Incredible (0)	9	4	0

Number of Mishaps

The risk matrix illustrates the distribution of mishaps according to their frequency of Class 1, Class 2, and Class 3 severity categories. The matrix is a valuable risk communication tool and helps decision makers understand how many mishaps fall into the various categories.

To develop a risk matrix from the preliminary risk analysis, total the number of mishaps within Class 1, Class 2, and Class 3 severity categories for each frequency category.

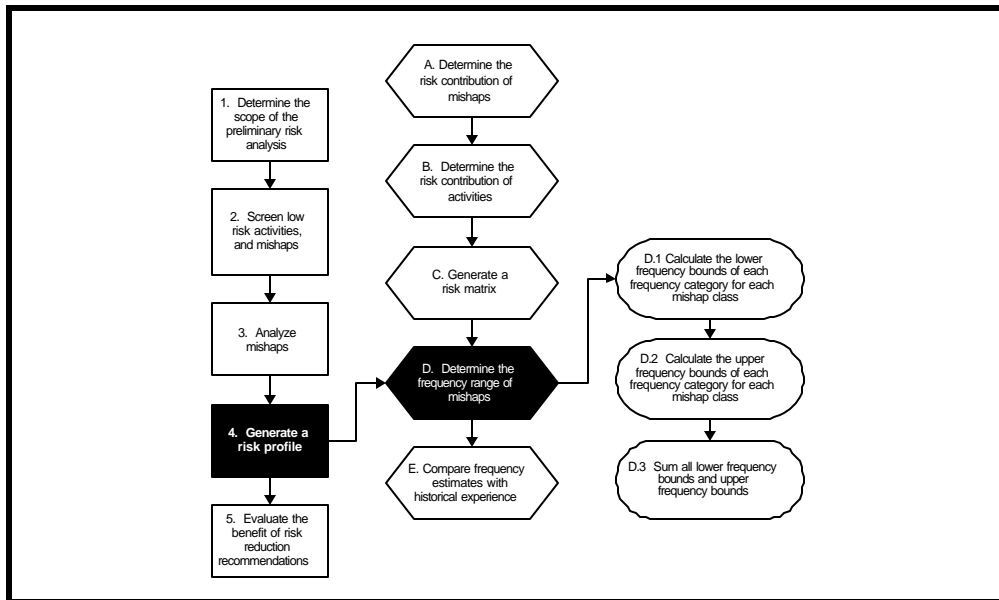
Example

There are two mishaps with a Class 2 risk score of 4.

Mishap	Frequency Scores		
	Class 1	Class 2	Class 3
Mishap 1	5	4	7
Mishap 2	2	4	7
Mishap 3	0	3	4
Mishap 4	1	2	6

	Category 1	Category 2	Category 3
Continuous (8)	0	0	0
Very frequent (7)	0	0	2
Frequent (6)	0	0	1
Occasional (5)	1	0	0
Probable (4)	0	2	1
Improbable (3)	0	1	0
Rare (2)	1	1	0
Remote (1)	1	0	0
Incredible (0)	1	0	0

Number of Mishaps



Step 4.D Determine the frequency range of mishaps

Frequency range — a lower and upper limit representing the estimated frequency of occurrence of a mishap category

The frequency of a Class 1, Class 2, and Class 3 mishap is determined by using the frequency bounds for the frequency categories shown in the risk matrix. The frequency bounds are defined in Step 3.B.

The frequency ranges for Class 1, Class 2, and Class 3 mishaps are useful in understanding the overall risk. They also provide a means to validate the frequency estimates in the preliminary risk analysis by comparing the estimates with historical mishap data described in the next section.

Overall frequency bounds for Class 1, 2, and 3 mishaps

Frequency Category	Frequency Bounds (per year)		Risk Matrix			Estimated Frequency Range for Class 1 Mishaps (per year)		Estimated Frequency Range for Class 2 Mishaps (per year)		Estimated Frequency Range for Class 3 Mishaps (per year)	
	Lower	Upper	1	2	3	Lower	Upper	Lower	Upper	Lower	Upper
Continuous (8)	100	1,000	0	0	0	0	0	0	0	0	0
Very Frequent (7)	10	100	0	0	2	0	0	0	0	20	200
Frequent (6)	1	10	0	1	5	0	0	1	10	5	50
Occasional (5)	0.1	1	1	2	9	0.1	1	0.2	2	0.9	9
Probable (4)	0.01	0.1	2	14	22	0.02	0.2	0.14	1.4	0.22	2.2
Improbable (3)	0.001	0.01	6	9	14	0.006	0.06	0.009	0.09	0.014	0.14
Rare (2)	0.0001	0.001	11	15	10	0.0011	0.011	0.0015	0.015	0.001	0.01
Remote (1)	0	0.0001	36	20	3	0	0.0036	0	0.002	0	0.0003
Incredible (0)	0	0	9	4	0	0	0	0	0	0	0
Frequency Range						0.1271	1.2746	1.3505	13.507	26.135	261.35

Steps to determine the frequency range of mishaps

- 4.D.1 Calculate the lower frequency bounds of each frequency category for each mishap class
- 4.D.2 Calculate the upper frequency bounds of each frequency category for each mishap class
- 4.D.3 Sum all lower frequency bounds and upper frequency bounds

Step 4.D.1 Calculate the lower bounds of the estimated frequency range for Class 1 mishaps by multiplying the lower frequency bounds times the number of mishaps with Class 1 mishaps in each frequency category

Frequency Category	Frequency Bounds (per year)		Risk Matrix			Estimated Frequency Range for Class 1 Mishaps (per year)		Estimated Frequency Range for Class 2 Mishaps (per year)		Estimated Frequency Range for Class 3 Mishaps (per year)	
	Lower	Upper	1	2	3	Lower	Upper	Lower	Upper	Lower	Upper
Continuous (8)	100	1,000	0	0	0	0					
Very Frequent (7)	10	100	0	0	2	0					
Frequent (6)	1	10	0	1	5	0					
Occasional (5)	0.1	1	1	2	9	0.1					
Probable (4)	0.01	0.1	2	14	22	0.02					
Improbable (3)	0.001	0.01	6	9	14	0.006					
Rare (2)	0.0001	0.001	11	15	10	0.0011					
Remote (1)	0	0.0001	36	20	3	0					
Incredible (0)	0	0	9	4	0	0					
Frequency Range											

Step 4.D.2 Calculate the upper bounds of the estimated frequency range for Class 1 mishaps by multiplying the upper frequency bounds times the number of mishaps with Class 1 mishaps in each frequency category

Frequency Category	Frequency Bounds (per year)		Risk Matrix			Estimated Frequency Range for Class 1 Mishaps (per year)		Estimated Frequency Range for Class 2 Mishaps (per year)		Estimated Frequency Range for Class 3 Mishaps (per year)	
	Lower	Upper	Class 1	Class 2	Class 3	Lower	Upper	Lower	Upper	Lower	Upper
Continuous (8)	100	1,000	0	0	0	0	0				
Very Frequent (7)	10	100	0	0	2	0	0				
Frequent (6)	1	10	0	1	5	0	0				
Occasional (5)	0.1	1	1	2	9	0.1	1				
Probable (4)	0.01	0.1	2	14	22	0.02	0.2				
Improbable (3)	0.001	0.01	6	9	14	0.006	0.06				
Rare (2)	0.0001	0.001	11	15	10	0.0011	0.011				
Remote (1)	0	0.0001	36	20	3	0	0.0036				
Incredible (0)	0	0	9	4	0	0	0				
Frequency Range											

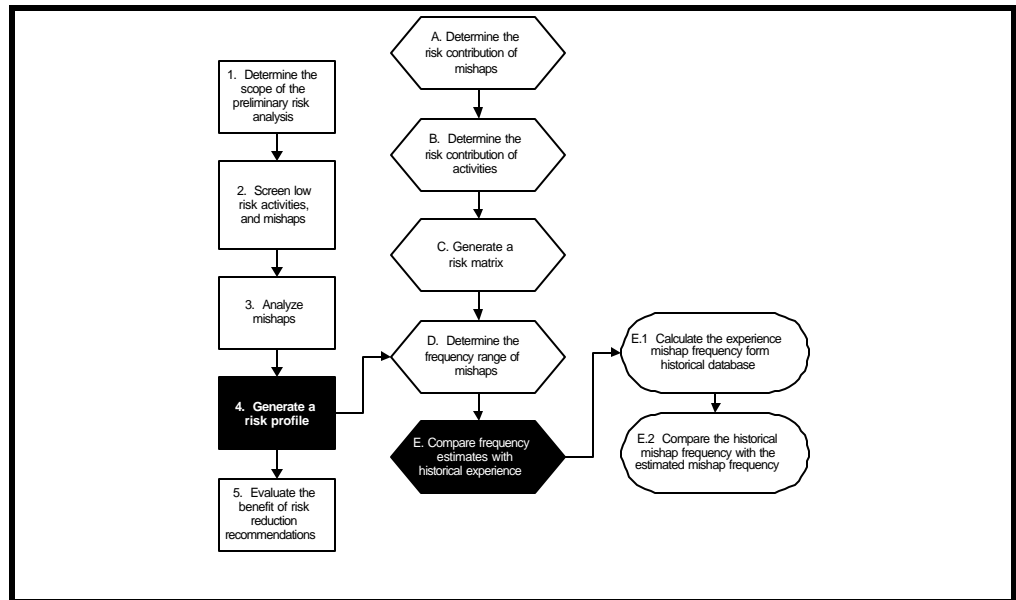
Step 4.D.3 Total the lower and upper bounds columns for the overall frequency bounds of Class 1 mishaps (repeat steps for all classes of mishaps)

Frequency Category	Frequency Bounds (per year)		Risk Matrix			Estimated Frequency Range for Class 1 Mishaps (per year)		Estimated Frequency Range for Class 2 Mishaps (per year)		Estimated Frequency Range for Class 3 Mishaps (per year)	
	Lower	Upper	Class 1	Class 2	Class 3	Lower	Upper	Lower	Upper	Lower	Upper
Continuous (8)	100	1,000	0	0	0	0	0				
Very Frequent (7)	10	100	0	0	2	0	0				
Frequent (6)	1	10	0	1	5	0	0				
Occasional (5)	0.1	1	1	2	9	0.1	1				
Probable (4)	0.01	0.1	2	14	22	0.02	0.2				
Improbable (3)	0.001	0.01	6	9	14	0.006	0.06				
Rare (2)	0.0001	0.001	11	15	10	0.0011	0.011				
Remote (1)	0	0.0001	36	20	3	0	0.0036				
Incredible (0)	0	0	9	4	0	0	0				
Frequency Range						0.1271	1.2746				

The data from the analysis can be summarized in the table below.

Facility	Typical Unit Frequency Range for Mishaps (per year)			Expected Number of Occurrences over 50 years		
	Category 1	Category 2	Category 3	Category 1	Category 2	Category 3
Facility 1	0.13 to 1.3	1.4 to 14	26 to 261	7 to 65	70 to 700	1300 or more

Expected number of occurrences over 50 years is determined by multiplying the frequency range for mishaps (per year) by 50. This information is useful in understanding the expected number of mishaps over the life of a vessel or facility. This can be calculated for any length of time of interest.



Step 4.E Compare frequency estimates with historical experience

Facility	Unit Class Estimated Frequency Range for Mishaps (per year)			Mishap Frequencies Based on Historical Mishap Data (per year)		
	Category 1	Category 2	Category 3	Category 1	Category 2	Category 3
Facility 1	0.13 to 1.3	1.4 to 14	26 to 261	0.1	5	109

Analyzing historical data provides a means to validate the preliminary risk analysis study. Historical data that are slightly higher than the estimated frequencies from the preliminary risk analysis may reflect:

- A lack of relevant experience among preliminary risk analysis team members with mishaps that occur infrequently (e.g., potential omissions in the list of mishaps or in the list of causes)
- Implementation of corrective actions to prevent repeated mishaps, reducing the frequency of future events
- A limited number of functions may have been reviewed during the preliminary risk analysis

Historical data that are slightly lower than the estimated frequencies from the preliminary risk analysis may reflect:

- Potential overlap in issues covered by the identified mishaps
- Overemphasis by the preliminary risk analysis team on certain events that occurred in recent years

Steps to compare frequency estimates with historical experience

- 4.E.1 Calculate the experienced mishap frequency from historical databases
- 4.E.2 Compare the historical mishap frequency with the estimated mishap frequency

Step 4.E.1 Calculate the experienced mishap frequency for class 1, class 2, and class 3 mishaps from historical databases

Frequency for a mishap class = (Number of events in the severity class)/
(Time Period)

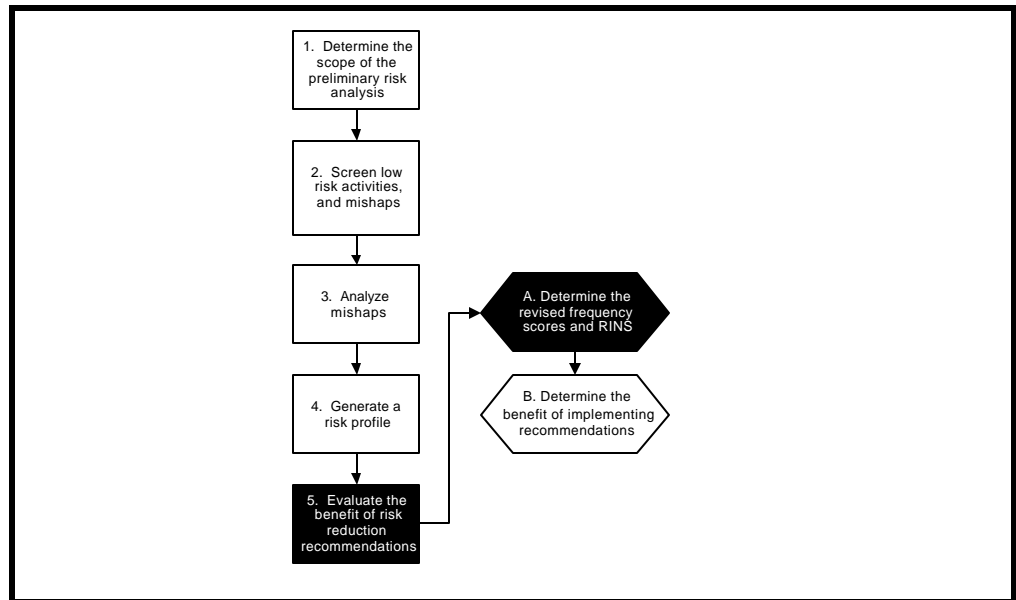
Example:

class 1 mishaps over a 10-year period = 1

Frequency of
Category 1 mishaps = 1/10
= 0.1 Category 1 mishaps per year

Step 4.E.2 Compare the historical mishap frequency with the estimated mishap frequency

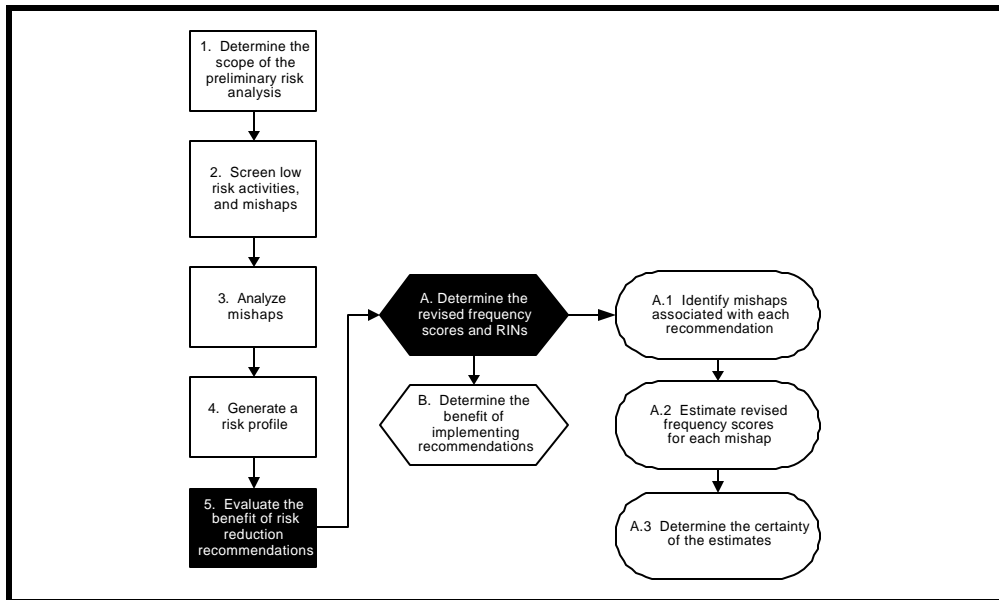
Facility	Unit Class Estimated Frequency Range for Mishaps (per year)			Mishap Frequencies Based on Historical Mishap Data (per year)		
	Category 1	Category 2	Category 3	Category 1	Category 2	Category 3
Facility 1	0.13 to 1.3	1.4 to 14	26 to 261	0.1	5	109



Step 5 Evaluate the Benefit of Risk Reduction Recommendations

Each recommendation from the preliminary risk analysis is designed to reduce the risk associated with the mishaps discussed during the analysis. These recommendations may serve as preventive or mitigative safeguards, and they may apply to more than one mishap.

This section provides a means to estimate the dollar/year savings due to the reduced risk realized by implementing recommendations. The dollar savings can be compared to the implementation cost of the recommendation in a cost/benefit analysis. Decision makers will use this cost/benefit analysis to decide if a recommendation should be implemented.



Step 5.A Determine the revised frequency scores and RINs

The benefit of implementing each preliminary risk analysis recommendation is estimated by determining the potential reduction in frequency scores of mishaps affected by the recommendations.

Preliminary Risk Analysis Recommendations	Associated Mishaps	Initial Frequencies	Revised Frequencies	Certainty in Revised Frequencies	Notes
Recommendation 1- Consider establishing worker fatigue guidelines	Cargo loading/unloading: Container Acute hazard Exposure: worker	3, 4, 3	1, 2, 3	Med	
	Cargo loading/unloading: Bulk (liquid) Acute hazard Exposure: worker	2, 4, 5	2, 4, 5	High	No significant risk reduction expected
Recommendation 2- Consider further automation of the loading/unloading operations	Cargo loading/unloading: Container Acute hazard Exposure: worker	1, 3, 6	2, 3, 4	Low	
	Cargo loading/unloading: Bulk (liquid) Acute hazard Exposure: worker	2, 4, 5	1, 3, 4	Med	

Steps to determine revised frequency scores and RINs

- 5.A.1 Identify mishaps associated with each recommendation
- 5.A.2 Estimate revised frequency scores for each mishap
- 5.A.3 Determine the certainty of the estimates

Step 5.A.1 Identify the mishaps associated with each recommendation and their frequency scores

Preliminary Risk Analysis Recommendations	Associated Mishaps	Initial Frequencies	Revised Frequencies	Certainty in Revised Frequencies	Notes
<i>Recommendation 1- Consider establishing worker fatigue guidelines</i>	Cargo loading/ unloading: Container Acute hazard Exposure: worker	3, 4, 3			
	Cargo loading/ unloading: Bulk (liquid) Acute hazard Exposure: worker	2, 4, 5			
<i>Recommendation 2- Consider further automation of the loading/unloading operations</i>	Cargo loading/ unloading: Container Acute hazard Exposure: worker	1, 3, 6			
	Cargo loading/ unloading: Bulk (liquid) Acute hazard Exposure: worker	2, 4, 5			

Step 5.A.2 Estimate revised Class 1, Class 2, and Class 3 frequency scores for each mishap affected by the recommendation

Preliminary Risk Analysis Recommendations	Associated Mishaps	Initial Frequencies	Revised Frequencies	Certainty in Revised Frequencies	Notes
<i>Recommendation 1- Consider establishing worker fatigue guidelines</i>	Cargo loading/unloading: Container Acute hazard Exposure: worker	3, 4, 3	1, 2, 3		
	Cargo loading/unloading: Bulk (liquid) Acute hazard Exposure: worker	2, 4, 5	2, 4, 5		
<i>Recommendation 2- Consider further automation of the loading/unloading operations</i>	Cargo loading/unloading: Container Acute hazard Exposure: worker	1, 3, 6	2, 3, 4		
	Cargo loading/unloading: Bulk (liquid) Acute hazard Exposure: worker	2, 4, 5	1, 3, 4		

Note:

Assume that the recommendation is effectively implemented.

For each mishap, estimate new frequency scores with the recommendation (new safeguard) in place. It may be necessary to review the preliminary risk analysis tables to understand the contributors and safeguards associated with the mishap.

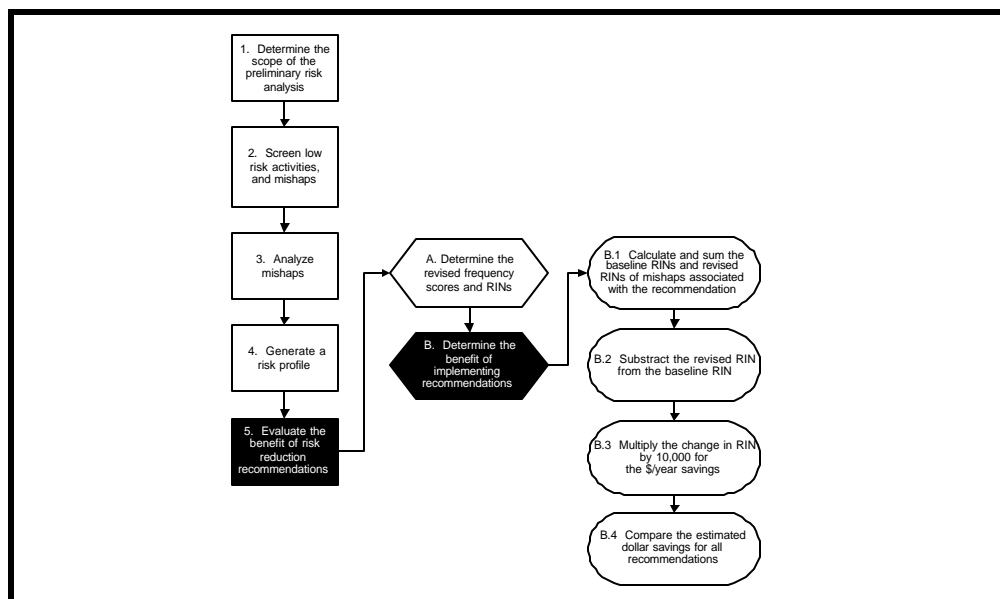
Step 5.A.3 Determine the certainty in the estimate of the revised frequency scores and provide any pertinent notes

Preliminary Risk Analysis Recommendations	Associated Mishaps	Initial Frequencies	Revised Frequencies	Certainty in Revised Frequencies	Notes
<i>Recommendation 1- Consider establishing worker fatigue guidelines</i>	Cargo loading/unloading: Container Acute hazard Exposure: worker	3, 4, 3	1, 2, 3	Med	
	Cargo loading/unloading: Bulk (liquid) Acute hazard Exposure: worker	2, 4, 5	2, 4, 5	High	No significant risk reduction expected
<i>Recommendation 2- Consider further automation of the loading/unloading operations</i>	Cargo loading/unloading: Container Acute hazard Exposure: worker	1, 3, 6	2, 3, 4	Low	
	Cargo loading/unloading: Bulk (liquid) Acute hazard Exposure: worker	2, 4, 5	1, 3, 4	Med	

Note:

Decision makers will have to consider whether frequencies in the Low certainty category should be used when determining the dollar benefit of the reduced risk.

The certainty characterizes the confidence in the assessment of the frequency scores. The certainty categories are High, Medium, and Low, and they are explained in Step 3.B.



Step 5.B Determine the benefit of implementing recommendations

The potential benefit gained from implementing a recommendation can be calculated by determining the change in the risk index numbers for the mishaps affected by the recommendations.

Recommendation	Mishaps	Baseline Average RIN	Revised Average RIN	Change in Average RIN	Average Risk Reduction (\$/year)
1	1	1.815	0.0183	1.797	17,970
	2	0.3465	0.3465		
	Total	2.1615	0.3648		
2	1	0.1980	0.1832	0.3266	3,266
	2	0.3465	0.0347		
	Total	0.5445	0.2179		

Steps to determine the benefit of implementing recommendations

- 5.B.1 Calculate and sum the baseline RINs and revised RINs of mishaps associated with the recommendation
- 5.B.2 Subtract the revised RIN from the baseline RIN to determine the change in RIN
- 5.B.3 Multiply the change in RIN by 10,000 for the \$/year savings
- 5.B.4 Compare the estimated range of dollar savings for all recommendations

Step 5.B.1 Calculate and sum the baseline RINs and revised RINs of mishaps associated with the recommendation (do this for average RIN, lower RIN, and upper RIN)

Recommendation	Mishaps	Baseline Average RIN	Revised Average RIN	Change in Average RIN	Average Risk Reduction (\$/year)
1	1	1.185	0.0183		
	2	0.3456	0.3465		
	Total	2.1615	0.3648		
2	1	0.1980	0.1834		
	2	0.3465	0.0347		
	Total	0.5445	0.2179		

Recommendation	Mishaps	Baseline Lower RIN	Revised Lower RIN	Change in Lower RIN	Lower Risk Reduction (\$/year)
1	1	0.2800	0.0028		
	2	0.038	0.038		
	Total	0.318	0.0408		
2	1	0.137	0.0281		
	2	0.038	0.0038		
	Total	0.0517	0.0319		

Recommendation	Mishaps	Baseline Upper RIN	Revised Upper RIN	Change in Upper RIN	Upper Risk Reduction (\$/year)
1	1	57.01	0.58		
	2	31	31		
	Total	88.01	31.58		
2	1	13	5.8		
	2	31	3.1		
	Total	44	8.9		

Note:

Decision makers will have to consider whether mishaps with an RIN in the Low certainty category should be used when determining the dollar benefit of the reduced risk

Tip:

$$\text{Average RIN} = (16.5 * 10^{(Fs1)} + 0.165 * 10^{(Fs2)} + 0.00165 * 10^{(Fs3)}) / 10,000$$

$$\text{Lower RIN} = (2.7 * 10^{(Fs1)} + 0.01 * 10^{(Fs2)} + 0.0001 * 10^{(Fs3)}) / 10,000$$

$$\text{Upper RIN} = (300 * 10^{(Fs1)} + 27 * 10^{(Fs2)} + 0.1 * 10^{(Fs3)}) / 10,000$$

Step 5.B.2 Subtract the revised RIN from the baseline RIN to determine the change in RIN (do this for average RIN, lower RIN, and upper RIN)

Recommendation	Mishaps 1	Baseline Average RIN	Revised Average RIN	Change in Average RIN	Average Risk Reduction (\$/year)
1	1	1.815	0.0183	1.797	
	2	0.3465	0.3965		
	Total	2.1615	0.3648		
2	1	0.1980	0.1832	0.3266	
	2	0.3465	0.0347		
	Total	0.5445	0.2179		

Recommendation	Mishaps 2	Baseline Lower RIN	Revised Lower RIN	Change in Lower RIN	Lower Risk Reduction (\$/year)
1	1	0.2800	.0028	0.2772	
	2	0.038	0.038		
	Total	0.318	0.0408		
2	1	0.0137	0.0281	0.0198	
	2	0.038	0.0038		
	Total	0.0517	0.0319		

Recommendation	Mishaps 3	Baseline Upper RIN	Revised Upper RIN	Change in Upper RIN	Upper Risk Reduction (\$/year)
1	1	57.01	0.58	56.43	
	2	31	31		
	Total	88.01	31.58		
2	1	13	5.8	35.1	
	2	31	3.1		
	Total	44	8.9		

Step 5.B.3 Multiply the change in RIN by 10,000 for the \$/year savings from the risk reduction (do this for the change in average RIN, lower RIN, and upper RIN)

Multiplying the RIN by 10,000 results in risk values stated in terms of potential dollar savings on a **yearly** basis.

Recommendation	Mishaps 1	Baseline Average RIN	Revised Average RIN	Change in Average RIN	Average Risk Reduction (\$/year)
1	1	1.815	0.0183	1.797	17,970
	2	0.3465	0.3465		
	Total	2.1615	0.3648		
2	1	0.198	0.1832	0.3266	3,272
	2	0.3465	0.0347		
	Total	0.5445	0.2179		

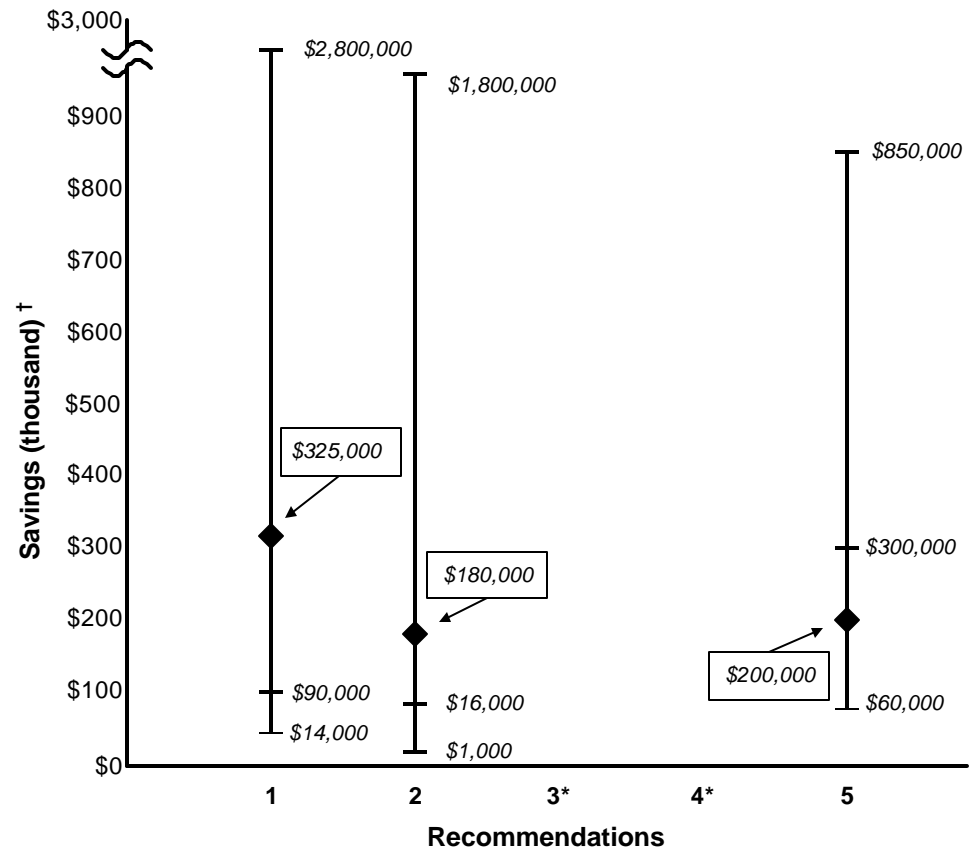
Recommendation	Mishaps 2	Baseline Lower RIN	Revised Lower RIN	Change in Lower RIN	Lower Risk Reduction (\$/year)
1	1	0.2800	.0028	0.2772	2,772
	2	0.038	0.038		
	Total	0.318	0.0408		
2	1	0.0137	0.0281	0.0198	198
	2	0.038	0.0038		
	Total	0.0517	0.0319		

Recommendation	Mishaps 3	Baseline Upper RIN	Revised Upper RIN	Change in Upper RIN	Upper Risk Reduction (\$/year)
1	1	57.01	0.58	56.43	564,300
	2	31	31		
	Total	88.01	31.58		
2	1	13	5.8	35.1	351,000
	2	31	3.1		
	Total	44	8.9		

Step 5.B.4 Compare the estimated range of dollar savings for all recommendations

The estimated range of dollar savings of each recommendation can be compared in several ways (see graph below). The comparison allows decision makers to decide which recommendation should be implemented and in what order. In the graph, savings are represented over a 5-year period by multiplying the savings calculated in the step on the previous page by 5. Any period of time can be chosen. The cost of implementing the recommendation can be included, as below, to assist decision makers in deciding whether to proceed with implementation or not.

Displaying all recommendations together allows comparison of recommendations so that resources can be spent on the most effective recommendations first.



* A reasonable estimate of savings is only possible after further review.

† Upper, lower, and average savings.

◆ Estimated total cost of implementing recommendation.

Note: Savings shown account for 5-year period.